

# Potential Near-Term Updates to the SAGE Model

Prepared by National Center for Environmental Economics (NCEE), U.S. EPA  
SAB CGE Model Review  
August 22, 2019

---

As with any modeling framework, the SAGE model will be subject to ongoing maintenance and development to improve its usefulness for evaluating the economic impacts of environmental regulations. While NCEE continues to pursue several longer-term research priorities in line with the recommendations of the prior SAB, we have also identified several near-term modeling goals. This memo outlines our broad approach to three potential improvements to model features that we anticipate making over the next couple of years: incorporating an empirically informed consumer demand system; generating a large open economy specification; and improving the representation of production, sales, and excise taxes. We seek input on the relative value of these improvements compared to other potential improvements as well as on specific methodologies, parameters, citations and other input that would be useful in pursuing these future improvements.

## 1 Empirically Informed Consumer Demand System

The specification of the consumer demand system is important for estimating the impact of environmental regulations. First, it plays a key role in determining the model's baseline (e.g., Cranfield et al., 2002). Second, it defines the final good demand curves that help determine the ability to control pollution on the extensive margin through the output effect. Third, it plays an important role in determining tax interaction effects (e.g., West and Williams 2007). The consumer demand system in computable general equilibrium (CGE) models is defined by an explicit or implicit specification of the utility function for the representative households. In the current version of SAGE, the utility function is defined as a nested constant elasticity of substitution (CES) function with calibrated substitution elasticities, similar to other related models.

Calibration is challenging, however, due to an absence of empirically estimated CES demand systems. This may be, in part, because assumptions implicit in the framework, such as homothetic preferences, do not align well with the data. Thus, empirical studies have often opted for more flexible functional forms. This disconnect between behavioral assumptions implied by the CES demand system and observed behavior

makes it difficult to calibrate such systems from parameters that are econometrically estimated using more flexible demand systems.

In response, some CGE models have elected to utilize more flexible consumer demand systems to capture additional characteristics of consumer behavior and better align with empirical estimates of cross-price elasticities and Engel curves. Numerous consumer demand system specifications have been used in CGE models, including the linear expenditure system (e.g., Chateau et al., 2014; Lofgren et al., 2002); constant differences of elasticities (e.g., McDougall et al., 1997; Chen, 2017); an implicitly direct additive demand system (e.g., Rimmer and Powell, 1996; Yu et al., 2003); and the translog demand system (e.g., Jorgenson et al., 2013; Goettle et al., 2007; and Cao et al., 2017).

Similarly, we propose to adopt a more flexible functional form for representing the consumer demand system in a future version of SAGE. There are documented tradeoffs between these specifications in terms of their complexity, regularity, ability to capture cross-price elasticities, Engel curve flexibility, and the number of commodities that can be reasonably accommodated. The application and regional coverage of studies that have implemented more flexible consumer demand systems varies widely, and most are not focused specifically on environmental policies in the United States. We, therefore, recognize that care must be taken when interpreting the results of these previous studies in our context. For example, while it has been shown that the robust Engel responses available with an implicitly direct additive demand system can be important for capturing baseline consumption patterns in countries expected to experience more rapid income growth, more parsimonious specifications such as the linear expenditure system may perform similarly along this dimension for the United States (Yu et al., 2003). We are currently evaluating the literature that examines the performance of different consumer demand systems and seek input from the Panel and the broader research community as to the relative merits of the available specifications for the specific purpose of estimating the impact of U.S. environmental regulations within a CGE modeling framework.

In adopting a more flexible form for the consumer demand system, we intend to empirically estimate region and income group-specific parameters for eventual incorporation into SAGE. For the estimation, we plan to combine Consumer Expenditure Survey (CEX) micro-use public data with estimated price levels following the approach of Aten (2006) to generate a time series of prices and quantities at the Census region level available in the public-use CEX data (SAGE regions are subsets of the Census regions). We intend to estimate several different flexible functional forms that are commonly used in the empirical literature, including variations that allow for non-monotonic income effects and heterogeneous cross-price

elasticities. If questions remain regarding the most appropriate specification, we may also explore the sensitivity of the SAGE model results to different functional forms, including both social cost and distributional impacts. This type of comparison could also more broadly consider the impact of additional consumer demand detail on estimates of the social costs for environmental regulations analogous to the effort of Lanz and Rutherford (2016). However, selecting a merit function to evaluate the relative performance of different preference specifications may be challenging.

## 2 Large Open Economy Specification

Currently, SAGE represents the United States as a small open economy, where the rest of the world's supply of imports to and demand for exports from the United States are perfectly elastic. In other words, world commodity prices are assumed to be unaffected by policy-induced changes within the United States. While this may be a reasonable local approximation, we have not evaluated its adequacy in the context of estimating the economic effects of large environmental regulations that directly affect highly trade-exposed industries. In such cases, the small open economy assumption may lead to an underestimate of the social costs of the regulation and an overestimate of incidence on the domestic regulated sector.

Multiple approaches have been used to model the United States as a large open economy in a CGE framework. The first are global models that explicitly represent production and consumption for all countries (at some level of aggregation) and require equilibrium in all international markets. There are several examples where CGE models with subnational detail in the United States have been embedded within or linked to global models that explicitly represent international supply and demand (e.g., Balistreri and Rutherford, 2001; Caron and Rausch, 2013; Ross, 2014). In these cases, the modeling structure of foreign economies generally mirrors that of the domestic economy, though with potentially different behavioral parameters. While this approach provides a robust method for implicitly representing the elasticity of international demand for U.S. export demand and import supply, it requires significant development and data resources. One moves from developing and maintaining a model of the domestic economy to developing and maintaining a model of the global economy. However, for most EPA regulations emphasis is placed on understanding their effects on the domestic economy.

A related approach incorporates a simplified representation of international producers, households, and governments into the model of the United States. For example, Goulder and Hafstead (2018) model the rest of the world as having a single representative household and government that mirror their domestic

counterparts in terms of structure and behavioral parameters and a single international firm with a simplified production function that produces all foreign output. This approach allows the world price of commodities to be determined endogenously. However, the simplified nature of the approach to foreign production results in a world price that is equal across all traded commodities.<sup>1</sup>

A third alternative is to endogenously model world prices based on explicitly defining a demand function for U.S. exports and a supply function for imports to the United States. A common approach to this alternative is to assume a constant elasticity of supply/demand function for each commodity, where the trade elasticity is negative in the demand for U.S. exports and positive in the supply of imports to the United States (e.g., Rausch et al., 2009; Gilbert and Tower, 2013). In the limit as the supply/demand elasticities approach negative and positive infinity, respectively, the model converges to that of a small open economy. This approach has the benefit of being parsimonious and may be calibrated from empirical estimates of trade elasticities. However, the approach is limited to capturing movements along the international supply and demand curves and will not be able to capture any shifts in these curves induced by U.S. policies.

We propose to begin with implementing the third approach of explicitly defining a demand function for U.S. exports and a supply function for imports to the United States for each commodity such that world prices are endogenous to the model. Within that framework we plan to identify a reasonable range for trade elasticities based on the empirical literature and extensively test the model within that range to evaluate the circumstances where the large open economy specification notably changes the results. We may also explore how much value is added from taking this approach over a wide range of specifications compared to a simplified representation where world prices are equal across commodities.

### 3 Improved Representation of Production, Sales, and Excise Taxes

IMPLAN social accounts explicitly track aggregate taxes on production through a composite tax on output composed of a variety of consumptive taxes (e.g. sales and excise taxes) and other indirect business taxes (e.g. property taxes and licensing fees). Though the SAGE model's build stream goes to considerable lengths to incorporate and distinguish between marginal and average tax rates on labor and capital in the underlying reference equilibrium, the composite tax on output is left aggregated. While the modeled tax on output does incorporate the overall magnitude of the tax receipts from the variety of consumptive and

---

<sup>1</sup> The exception in Goulder and Hafstead (2018) are crude oil prices, which are defined exogenously in their framework.

indirect business taxes, it does not assign these various tax types to their respective margins. This is particularly true of excise and sales taxes, where the majority are applied as a production tax on the retail sector, that collects the taxes, rather than specifically on the taxed commodity. Moreover, assessing taxes on the output of sectoral production effectively taxes regional, national, and international supply but not imports. This model update will attempt to disaggregate the production tax into excise, sales and other tax types and shift these resulting tax flows from the production side of the model to the consumption side, which will better characterize tax incidence both regionally and across income quintiles.

Distortionary taxes that drive a wedge between producer and consumer prices generate deadweight loss in the economy, and assessing the economic incidence depends on the type of tax imposed and the way it is represented in a model (Fullerton and Metcalf, 2002). The way in which taxes are characterized in a general equilibrium setting has been shown to be an important determinant of the magnitude of the costs of a policy, due to notable tax interaction effects. A large literature has focused on quantifying the ways in which pre-existing distortions interact with policy goals, particularly the potential for environmental policies to exacerbate tax distortions in the labor market (e.g. Goulder, Parry, Burtraw (1997)). Of particular relevance to this model improvement, Goulder and Williams (2003) find that there can be significant tax interactions when a taxed commodity is relatively substitutable with leisure. While this relative substitutability will be determined through assumed preferences, appropriately capturing this interaction effect requires that consumption taxes are applied to the proper margin.

Other CGE models of the United States economy use comparable data inputs, and likewise have a similar tax structure to the current SAGE framework, especially those models with sub-national detail built on the IMPLAN data set. For example, the U.S. Regional Energy Policy (USREP) model (Rausch et al. 2010), applies similar aggregate ad-valorem output taxes based on the average tax rate implied in the IMPLAN data. National level models without the need to account for regional heterogeneity in the tax rates, conversely, tend to have more detail in their respective structure of output and consumption taxes. For example, the Intertemporal General Equilibrium Model (IGEM) separately recognizes sales, property and estate taxes (Jorgenson et al., 2013). The aim of this model improvement is to integrate more of the richness of the tax structure common in national level model into a model with sub-national resolution.

We anticipate that the disaggregation of production taxes into its sales, excise and other components will be based on empirical tax flow data. Because SAGE is a regional model, we would use information collected by Census from the Annual Survey of State Government Tax Collections and Annual Survey of Local Government Finances to align state and local tax flows with national tax flows in the National Income

and Product Accounts table. These data sources can generate region-specific tax shares that may allow us to disaggregate production taxes in the IMPLAN dataset to generate average production and consumption tax rates. With this disaggregation, a remaining challenge will be determining the allocation of these taxes to their respective margins. These decisions will in part be governed by the structure of the data in the underlying IMPLAN social accounts as the tax flows associated with excise and sales taxes are not always assessed on the taxed commodity but rather on its supply through retail sectors.

## References

- Aten, B. 2006. "Inter-area price levels: an experimental methodology." *Monthly Lab. Review* 129-147.
- Balistreri, E., and T. Rutherford. 2001. Dynamic general equilibrium analysis at the state level: assessing the economic implications of the Kyoto Protocol. Working paper. Presented at the Fourth Annual Conference on Global Economic Analysis. Purdue University, Indiana, June 27-29.
- Cao, J., M. Ho, W. Hu, and D. Jorgensen. 2017. "Urban Household Consumption in China." Harvard-China Project on Energy, Economy, and Environment, Harvard University. Working Paper.
- Caron, J., and S. Rausch. 2013. A global general equilibrium model with US state-level detail for trade and environmental policy analysis – technical notes. Joint Program Technical Note #13. Massachusetts Institute of Technology.
- Château, J., R. Dellink. and E. Lanzi. 2014. An overview of the OECD ENV-Linkages model: version 3. OECD Environment Working Paper, No. 65. Organisation for Economic Cooperation and Development.
- Chen, Y. 2017. The Calibration and Performance of a Non-homothetic CDE Demand System for CGE Models. *Journal of Global Economic Analysis*, 2(1), 166-214.
- Cranfield, J., P. Preckel, J. Eales, T. and Hertel. 2002. "Estimating consumer demands across the development spectrum: Maximum Likelihood estimate of an implicit direct additivity model." *Journal of Development Economics* 68: 289-307.
- Fullerton, D., and G. Metcalf. 2002. Tax incidence. *Handbook of Public Economics*, 4, 1787-1872.
- Goettle, R., M. Ho, D. Jorgenson, D. Slesnick, and P. Wilcoxon. 2007. "IGEM, an inter-temporal general equilibrium model of the US economy with emphasis on growth, energy and the environment." Prepared for the US Environmental Protection Agency, EPA Contract No. EP-W-05-035.
- Goulder, L., and M. Hafstead. 2018. Confronting the Climate Challenge. Columbia University Press, New York.
- Goulder, L., I. Parry, and D. Burtraw. 1997. Revenue-raising versus other approaches to environmental protection: The critical significance of preexisting tax distortions. *The Rand Journal of Economics*, 28(4), 708.

- Goulder, L., and R. Williams III. 2003. The substantial bias from ignoring general equilibrium effects in estimating excess burden, and a practical solution. *Journal of Political Economy*, 111(4), 898-927.
- Jorgenson, D., R. Goettle, M. Ho, and P. Wilcoxon. 2013. *Double dividend: environmental taxes and fiscal reform in the United States*. MIT Press.
- Lanz, B., and T. Rutherford. 2016. "GTAP in Gams: Multiregional and small open economy models." *Journal of Global Economic Analysis*, 1(2), 1-77.
- Lofgren, H., R. Harris, and S. Robinson. 2002. *A standard computable general equilibrium (CGE) model in GAMS* (Vol. 5). Intl Food Policy Res Inst.
- McDougall, R., A. Elbehri, and T. Truong. 1998. *Global Trade Assistance and Protection: The GTAP 3 Data Base*, Center for Global Trade Analysis, Purdue University
- Rausch, S., G. Metcalf, J. Reilly, and S. Paltsev. 2009. "Distributional Impacts of a U.S. Greenhouse Gas Policy: A General Equilibrium Analysis of Carbon Pricing." MIT Joint Program on the Science and Policy of Global Change Report 182.
- Rausch, S., G. Metcalf, J. Reilly, and S. Paltsev. 2010. Distributional implications of alternative US greenhouse gas control measures. *The BE Journal of Economic Analysis & Policy*, 10(2).
- Rimmer, M. and A. Powell. 1996. "An Implicitly additive demand system." *Applied Economics* 28: 1613-1622.
- Ross, M. 2014. Structure of the dynamic integrated economy/energy/emissions model: computable general equilibrium component, DIEM-CGE. Nicholas Institute for Environmental Policy Solutions Working Paper 14-12. Duke University: North Carolina.
- West, S., and R. Williams. 2007. "Optimal taxation and cross-price effects on labor supply: Estimates of the optimal gas tax." *Journal of Public Economics* 91(3-4): 593-617.
- Yu, W., T. Hertel, P. Preckel, and J. Eales. 2003. "Projecting world food demand using alternative demand systems." *Economic Modelling* 21(1): 99-129.